4-inch Diameter InP Single Crystals with Low Dislocation Density Manufactured by VCZ Method

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1. Introduction

InP substrates are the best material for high frequency devices and high capacity WDM optical communication systems. In this field, cost reduction as well as higher device performance are the most important targets for device manufacturers to overcome intense competition and to obtain larger market share. The 4-inch process is the key technology to reach the cost reduction goal. However, manufacturing of 4-inch InP crystal had not been successful due to high frequency of twinning. We have overcome twinning problem by stabilizing the temperature fluctuation in a VCZ (Vapor pressure controlled Czochralski) puller, and have succeeded in manufacturing high quality 4-inch InP substrates with low dislocation density.

2. Crystal growth

InP single crystals are grown under a magnetic field in a VCZ puller with a multi-zone heater system. A detailed description of crystal growth is referenced by Hosokawa et.al.[1]. We have succeeded in the growth of 4-inch S-doped InP single crystals.

The current focus of our development is stabilizing temperature fluctuation in VCZ puller, which is thought to be the cause of twinning. InP crystals have been grown under a highly pressurized nitrogen atmosphere, where large temperature fluctuations are caused by instable nitrogen gas flow. We thought that the temperature fluctuation could be suppressed by decreasing gas flow rate, which depends on the temperature difference (ΔT) and the gas flow length (ΔL). We optimized ΔT and ΔL in the hot zone of a VCZ puller, which resulted in significant decrease of temperature fluctuation as shown in Fig.1. A picture of a 5kg 4-inch S-doped InP single crystal is shown in Fig. 2. Dislocation distributions of the substrates at the shoulder and at the tail of a 4-inch crystal are shown in Fig. 3. Slip-like dislocations exist around the peripheral region on the substrate at the shoulder, where large thermal stress is caused due to the large heat release from the cone part of the crystal. Only a few dislocations exist on the substrate at the tail.

4-inch S-doped and 4-inch Fe-doped InP crystals have been grown with high reproducibility. Figure 4 shows the comparison of dislocation density between 3-inch LEC, 3-inch VCZ and 4-inch VCZ InP single crystals doped with Sulfur or Iron. The dislocation density of 4-inch VCZ crystals is lower than that of 3-inch LEC crystals, but a little higher than that of 3-inch VCZ crystals. The thermal environment during crystal growth and the cooling process of 4-inch VCZ crystals have not been optimized yet. We have an aggressive plan to improve crystal quality and to develop longer length 4-inch crystals. SEI expects to rapidly achieve manufacturing volumes of longer length 4-inch crystals with lower dislocation density.

3. Wafer processing

We have improved the flatness by modifying the method of pasting the wafer on the polishing plate. TTVs before and after improvement are shown in Fig. 5. Further flatness improvements of 4-inch substrates are currently under development.

References

[1] Hosokawa et.al., Proc. of 10^{th} Intern. Conf. on Indium Phosphide and Related Materials, Tsukuba, Japan, (1998) 34-37